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BREWERS' AND DISTILLERS' BYPRODUCTS AND YEAST IN LIVESTOCK FEEDING 1/

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INTRODUCTION

In the manufacture of beer, distilled liquors and alcohols, vinegar and yeast, various byprcducts having considerable value in livestock feeding are recovered after cereal grains or other carbohydrate-containing raw materials have been fermented by yeast or other micro-organisms. These byproducts include spent grains, slops, and brewers' yeast. Recent improvements in the processes used in some of the larger distilleries have replaced the distillers' wet or dry spent grains and distillers' slop by distillers' solubles, distillers' dried grains with solubles, distillers' oil-extracted dried grains, and oils. All of these byproducts of the fermentation industries contain liberal quantities of proteins; the carbohydrate content is much lower than in the raw materials; and those byproducts that contain yeast and yeast-formed substances or other micro-organisms and their products are valuable sources of the B vitamins.

For the year ended June 30, 1942, the production of distillers' dried grains amounted to approximately 300,000 tons, an increase of more than 50 percent over that of the preceding year; and the production of brewers' dried grains was approximately 140,000 tons, an increase of more than 30 percent over the preceding year. Further great increases in the production of distillers' grains, due to the production of alcohol for war purposes, are anticipated. It is also possible that further developments in the production of yeasts, from such wastes as the spent sulfite liquor of the paper-pulp and cellulose industries, may provide additional large quantities of wood-sugar yeast for livestock feeding.

Yeast Action and Composition

Yeasts are unicellular plants. Under favorable conditions they grow rapidly and reproduce by budding or fission; under less favorable conditions they may form spores. The yeast cells absorb sugars, minerals, and other substances from the medium in which they are grown, synthesize proteins, enzymes, and other cell constituents, and multiply rapidly. At the same time the medium undergoes important changes. Sugars, originally present or formed from starches or other carbohydrates in the medium, are converted into alcohol and carbon dioxide by enzymes from the yeast and some other constituents are removed to become parts of the yeast cells. Yeast not only synthesizes the several members of the vitamin B group, such as thiamin, riboflavin, niacin, pyridoxine, pantothenic acid, choline, para-aminobenzoic acid, and probably others, but also absorbs most of these from the medium. Yeast is therefore an excellent source of the B vitamins. Also, yeast can synthesize ergosterol, particularly when incubated in an aerated sugar-phosphate solution, and ergosterol is convertible into vitamin D, the antirachitic vitamin, by ultraviolet irradiation. The other known vitamins either are absent from yeast or are present in quantities so small as to be negligible.

The quantities of vitamins present in yeast vary considerably with the species, but may vary even more with the conditions under which the yeast is grown and the subsequent treatment it receives. Of the many species of yeasts, only those known as brewers' yeast, bakers' yeast, and wood-sugar yeast are considered in connection with feeding. Of these, brewers' yeast is richest, and wood-sugar yeast poorest in thiamin; brewers' yeast is poorest and wood-sugar yeast richest in riboflavin.

The dried yeast cells from different species are very similar in composition. Yeast cells, alone and completely dried, contain at least 50 percent of protein of good quality, about 2 percent of fat, 30 to 40 percent of nitrogen-free extract (largely carbohydrates), and 2 to 10 percent of ash. For the product to be marketed as yeast, some States require it to have a protein content of 45 percent or more. Cereals or minerals or both are also present in cereal-yeast feeds and other commercial yeast-containing feedstuffs. These products are lower in protein content than yeast and differ widely in quantities of other constituents.

Byproducts of Fermentation

Brewing and the manufacture of distilled liquors, alcohol, vinegar, and yeast, all involve the conversion of sugars originally present or derived from starches or other carbohydrates into alcohol and carbon dioxide by the action of yeast or other micro-organism and yield various byproducts which have value in animal feeding. The value of these byproducts depends on the raw materials used, the changes they undergo during the manufacture of the chief product, and the process of byproduct recovery. As the chief concern of the industries is in the main product, the byproducts show wide variations in composition and vitamin content.

If, as is usually the case in these industries, the carbohydrate containing raw materials are the cereal grains, the removal of much of the starch and the more soluble of the other constituents leaves spent-grain residues. These retain practically all the fiber and much of the protein, fat, and mineral of the original grains. The action of the yeast or other micro-organism increases the quantity of the B vitamins and also collects much of these vitamins originally present in the medium. Consequently, only the yeast and those byproducts that contain yeast, or other micro-organisms or their products contain sufficient quantities of the several members of the vitamin B group to be considered as good sources of these vitamins. Vitamins A, C, and D, if present at all, are in quantities too small for consideration. The spent grains retain their form but the total solids and digestible constituents are greatly reduced. Like the grains from which they are derived the spent grains are low in calcium. On the water-free basis, the relative quantities of fiber, fat, and protein are higher and the digestible carbohydrates far lower than in the original grains. The proteins of the spent grains are deficient in some of the essential amino acids, a characteristic of cereal proteins in general.

The spent grains are valuable feedstuffs because of their high protein and fat contents but they should seldom constitute over one-fourth of the entire ration. To meet the animal's requirements in both quantity and quality, it is necessary to make careful selection of the other feedstuffs in the ration. A protein concentrate of a noncereal type, as tankage, cotton-seed meal, linseed meal, fish meal, or dairy byproduct, a good source of vitamin A or of vitamins A and D, and adequate quantities of calcium should be included. In some cases the use of such feeds as legume hays will provide the calcium needed; otherwise some form of calcium carbonate, such as ground limestone or oyster shell, should be fed as a supplement.

BREWING AND BREWERY BYPRODUCTS

In the first step of the brewing process the malt is made. The grain, usually barley, is cleaned, softened in water for 2 to 3 days, and then held at the proper temperature until it sprouts. The enzyme, diastase, increases greatly and converts a part of the starch into sugar. The sprouted barley is then dried; the young roots and shoots become shrivelled and are separated from the grain. These are known as malt sprouts. The remainder of the grain is the malt.

In the second step the malt is crushed and "mashed," that is, water is added, and the mixture, either alone or with the addition of corn grits, rice grits, or other starch-containing material, often precooked to gelatinize the starch, is maintained at the proper temperature for the diastase to convert most of the starch present into malt sugar. The liquid extract separated from this mash is the wort, and the residue is the brewers' wet grains. These latter, dried, are brewers' dried grains.

In the third step the hops are added to the wort, the mixture is boiled, and the spent hops 2/ are removed by filtration.

In the final step yeast is added to the filtered extract and the sugars present are allowed to ferment. The yeast increases greatly and the sugar is converted into alcohol. The yeast is separated from the beer and is dried and sold as brewers' dried yeast, or it may be mixed with the spent grain and malt sprouts, or otherwise disposed of.

Brewers' Wet Grains

In the customary brewery practice the brewers' wet grains contain about 75 percent of water and 25 percent of grain residue. With due allowance for the water content, the brewers' wet grains are classed with concentrates. These grain residues are much higher in protein and fat and lower in fiber than corn silage or other common roughages. In the digestible nutrients, the brewers' wet grains are equivalent to corn silage, weight for weight, but are equivalent to only one-fourth of their weight in the brewers' dried grains.

Because of their high water content, these wet grains are not an economical feed unless the haul is short and they are as cheap as silage or less than one-fourth the price of grain. Furthermore, they are perishable and therefore in hot weather should be hauled fresh from the brewery every day or two. The wet grains may be kept a little longer if a small quantity of salt is sprinkled through the mass and the salted mixture thoroughly compacted in a silo of small diameter. It is essential that containers and mangers be kept thoroughly clean and free from spoiled material at all times. This is facilitated by the use of concrete mangers that are crevice-free.

2/ The spent hops are little used as a feedstuff but are of some value as fertilizer or may be used in the manufacture of cardboard.

For Dairy Cows: Brewers' wet grains, up to 20 to 30 pounds per head per day, may be used in feeding dairy cattle. The wet grains may replace an equal weight of silage or may substitute for a part of the grain in the ration, at the rate of 4 pounds of the wet grains for each pound of grain replaced. In order to avoid any possibility of tainting the milk, it is advisable to feed the wet grains only after milking and to store them outside the stable. Because of the neglect of these precautions, or the excessive feeding of the wet grains in some instances, their use in the feeding of dairy herds has been regulated or prohibited by some boards of health.

For Other Livestock: Brewers' wet grains may be fed to beef cattle and other classes of livestock as a part of the ration only. For horses, the upper limit is about 20 pounds per head per day, and for pigs, not over 2.5 pounds per 100 pounds of live weight.

Brewers' Dried Grains

For convenience and economy in large scale handling, the water content of the spent grains from the brewery is reduced to about 7 percent. One pound of the brewers' dried grains, thus prepared, contains all the dry matter from 4 pounds of the wet grains. The differences in the original barley and in the details of manufacture and byproduct recovery in the individual breweries result in some differences in the composition of the spent grains. The brewers' dried grains are, however, a protein concentrate. Their average composition is 7.3 percent water, 25.5 percent protein, 16 percent fiber, 6.6 percent fat, 40.8 percent nitrogen-free extract, and 3.8 percent minerals. The nitrogen-free extract contains relatively little starch and sugar and is, therefore, of less feeding value than the corresponding fraction of the original grains in which the starches and sugars are the chief constituents. Although brewers' dried grains contain about 93 percent of dry matter, only about 65 percent is total digestible nutrients. This includes 21 percent digestible protein.

The brewers' dried grains are bulky and keep fairly well in storage. They may be used to advantage as a part of the concentrate ration for dairy cows and beef cattle, but it is desirable to include other feedstuffs in order to provide a variety of proteins and to improve the palatability.

For Dairy Cows: In the feeding of dairy cows for milk production, brewers' dried grains, up to 5 or 6 pounds per head per day, may be used advantageously to provide additional protein in the ration. They are rated as worth about 85 percent as much as corn-gluten feed. For high-producing cows, brewers' dried grains may constitute as much as one-third of the total grain ration. Some other high-protein feed, such as cottonseed meal, linseed meal, or possibly wheat bran, should be included in the mixture, if the roughage part of the ration is low in protein; otherwise, cereal grains may be used in the mixture with brewers' dried grains.

For Beef Cattle: For the fattening of cattle, brewers' dried grains have about the same value as oats. Their use should not exceed one-third of the total grain ration.

For Sheep: Brewers' dried grains are little used for sheep feeding in the United States, but in Europe, they are valued highly for this purpose, especially in feeding suckling ewes. For fattening sheep, quantities up to 1 pound per head per day may be fed. In one experimental trial, better results were obtained with brewers' dried grains than with oats, wheat, or barley when fed together with rutabagas, hay, and cottonseed or linseed cake supplement.

For Horses: Brewers' dried grains have not been popular as a horse feed, because they are not very palatable and have a tendency to cause constipation. It is generally recommended that the quantity of brewers' dried grains be limited to one-fourth of the total concentrates in the rations for horses. One State experiment station has reported satisfactory results with a 1,000-pound work horse fed a ration of 8 pounds of brewers' dried grains, 2 pounds of bran, 4 pounds of corn, and 6 pounds of hay.

For Hogs: The bulkiness and high fiber content of the brewers' dried grains make them unsatisfactory for fattening hogs. As much as 10 percent may be included in a mixed feed composed chiefly of cereal meals. They are about equivalent to oats for breeding stock, specially sows.

For Poultry: In poultry feeding the quantity of brewers' dried grains should be limited to about 15 percent because of their high fiber content. Up to this limit, however, the protein content gives brewers' dried grains considerable value in poultry feed.

Malt Sprouts

As the quantity of malt sprouts produced is only about one-tenth as great as that of brewers' dried grains, the dried sprouts are a relatively less important byproduct. Frequently they are mixed with the spent grains and sold with them. The dried malt sprouts contain little fat, but are otherwise similar to brewers' dried grains in bulk, composition, and digestible nutrients. Their water-absorbing capacity makes them mold easily if not properly stored and they are dusty and rather unpalatable. The dried malt sprouts are best utilized with other grains or concentrates in quantities not exceeding 15 percent of the ration. They may be fed to livestock for which brewers' dried grains are satisfactory

For Dairy Cows: Malt sprouts may be included in the regular grain mixture for dairy cows up to a limit of 10 to 15 percent of the total weight of the mixture or they may be moistened and allowed to stand for several hours to render them more palatable and then mixed with grain or silage at feeding time. If more than 2 pounds per cow per day is used, the cows may refuse the feed, and the use of as much as 3.5 pounds per day may impart a bitter flavor to the milk.

DISTILLING ND DISTILLERY BYPRODUCTS

In the manufacture of ethyl alcohol and distilled liquors from grain, the mash, in which starches are converted into sugars, is prepared from malt and such cereal grains as barley, rye, or corn, and now also wheat; the entire mash is fermented by the action of brewers' yeast, and the fermented mash is separated by distillation into the alcohol-containing fraction and a watery residue. This latter is the dis-

tillery slop and contains about 94 per cent of water and the less volatile constituents of the fermented mash -- the spent grains, yeast and yeast products, minerals, and other dissolved or finely divided suspended substances, originally present or formed during the manufacturing process.

If potatoes, molasses, waste liquor from paper-pulp manufacture, or certain other waste products furnish the carbohydrates, and appropriate fermentation agents and processes are used, ethyl alcohol, butyl alcohol, acetone, or other valuable products are produced. The fermentation agents include brewers' yeast, certain other species of yeasts and other specific micro-organisms. The choice of the agent depends upon the ability of the specific organism to act upon the particular raw material and produce the desired end product. The separation of the volatile products by distillation leaves distillery slops of widely varying compositions and values. The quantity of digestible nutrients may be very low; however, if yeast is produced in quantity during the fermentation it is valuable both as a good protein and for its vitamin content; or, if certain micro-organisms have been used a riboflavin concentrate may be economically prepared from the slop.

As most distilleries use grains as raw material, large quantities of grain-containing slops result. The coarser solid material of grain-distillery slop, when strained out, is distillers' wet grains -- either corn or rye distillers' wet grains, depending on which grain predominates. If dried, they are corn or rye distillers' dried grains. The remaining liquid portion contains the dissolved and fine suspended substances and 95 percent or more of water. This is the distillers' thin solubles, formerly called distillers' thin slop or distillers' strained slop. The distillers' solubles contain yeast and yeast products, minerals, easily digested proteins, other nutrients, and dispersed fiber. The thin solubles may be concentrated by settling, centrifuging, or removal of water by evaporation, preferably under reduced pressure. Concentration of the thin solubles to a 40-percent water content produces corn or rye distillers' semi-solid solubles. If the water content is further reduced to between 12 and 7 percent, corn or rye distillers' dried solubles results. If the semi-solid solubles are added to the wet grains, corn or rye distillers' grains with solubles are produced and the drying of this mixture yields corn or rye distillers' dried grains with solubles.

Distillery Slop and Thin Solubles

The total digestible nutrients in the whole slop containing the spent grains are approximately 5.6 percent and in the strained slop or thin solubles they are not over 4 percent. From 20 to 25 percent of the digestible nutrients are proteins and from 12 to 20 percent are fats. As the yeast and some yeast products, or the micro-organisms and some of their products, remain in the thin solubles, some vitamins of the B group are present and, if precautions for their retention and preservation are observed, the solubles are a good source of these vitamins.

The whole slop with corn predominating is more valuable than that with a higher rye content because the rye slop contains more fiber, considerably less total digestible nutrients, and little more than one-half the quantity of digestible protein contained in the corn slop. The use of much wheat in distilleries is so recent that adequate information about the value and uses of wheat distillery slop is not yet

available. Slop is highly perishable and the concentration of the nutrients is so low that its use far from the distillery does not pay, even when it is free for the hauling. It takes 14 pounds, or nearly 2 gallons of slop to furnish the quantity of nutrients found in 1 pound of grain or in 3.5 pounds of corn silage. When used, the whole slop should be supplemented with other concentrates, good legume or grass hay, and usually also with powdered limestone or some other form of calcium carbonate. Feeders are also cautioned that the slop may sometimes be unduly laxative and are advised to feed straw, beet pulp, cottonseed hulls, oat mill feed, or oat hulls to counteract the effect. In feeding distillery slop, the same sanitary precautions are necessary as were recommended for use of brewers' wet grains.

For Beef Cattle: Distillery whole slop has been used extensively in fattening cattle. An average beef animal weighing 1,000 pounds can consume as much as 200 pounds of slop daily. As this quantity of slop contains only about 12 pounds of dry matter, it is necessary to supplement it with 15 to 20 pounds of dry feed, consisting of approximately half concentrates and half roughage, for a satisfactory rate of fattening. The supplement should include about 2 pounds of high protein concentrate, such as cottonseed meal, and 8 pounds of good legume hay. Salt and calcium carbonate must be provided but no additional water.

When whole slop is used for fattening beef cattle it is customary to give it to the lower grade of feeder cattle, which do not justify more than 3 to 4 months' feeding. They are often kept in sheds adjacent to the distillery and the slop is distributed to them, hot, through troughs.

For Dairy Cows: Fresh distillery whole slop may be used for dairy cows. The quantity should not exceed 8 to 10 gallons, or the equivalent of about 5 to 6 pounds of grain mixture or 17 to 20 pounds of corn silage, per cow per day, and then only to supplement a well-balanced dairy ration. When distillery whole slop is fed, corn silage and other succulent feeds should be omitted or their quantities limited. Hay, preferably green and leafy, and calcium carbonate should be fed in sufficient quantities to provide vitamins and minerals.

For Hogs: Not over 1½ gallons of whole slop per day per 100 pounds of live weight may be fed advantageously to fattening hogs or to brood sows, and this can replace only about one-fifth of the entire ration. If large quantities of slop are fed, the quality of the protein and carbohydrate portion and the calcium carbonate content of the ration must be given special attention.

Pigs fed distillers' whole slop alone do not make rapid gains. The daily gain per pig averages only from 0.25 to 0.50 pound, depending on the quality of the slop. Thin slop should be settled, the top liquid discarded and only the thicker portion fed. Distillers' slop added to a straight corn diet does not produce as rapid gains as when fed in addition to a liberal ration consisting of corn or other grain and a protein supplement of tankage and fish meal. In some experiments gains of 1.48 to 1.63 pounds per pig per day were made by pigs with initial weights of approximately 110 pounds when distillers' thin slop or thin solubles, in addition to varying quantities of corn and tankage, was fed. The ratio, in pounds, of corn to settled slop was not less than 1 to 5 and all the pigs were given free access to tankage. The feeding of distillers' slop or solubles appears to cause softer fat and leaner pork.

For Poultry: The distillers' thin solubles do not contain sufficient nutrients to be a practical feed for poultry.

Distillers' Wet Grains

The distillers' wet grains resemble the brewers' wet grains in composition and nutritive value. If corn predominates, the distillers' wet grains are somewhat more valuable than the brewers' wet grains, but if rye is the chief grain, their value is considerably less. The dry-matter content of corn distillers' wet grains is little more than 22 percent and the total digestible nutrients not over 20 percent. The quantities of total digestible nutrients and digestible proteins in the wet rye grains are less than two-thirds as great as in the wet corn grains. The calcium content is low.

There is no economy in the use of distillers' wet grains unless the haul is short and the wet corn grains are as cheap as silage or are sold at one-fourth, or less, the price of grains, or the wet rye grains are considerably cheaper. Furthermore, distillers' wet grains are highly perishable.

The distillers' wet grains may be used in approximately the same quantities and for the same purposes as the brewers' wet grains. The remainder of the ration must be adjusted for proper balance and the same sanitary precautions observed as were recommended in connection with the feeding of brewers' wet grains.

Distillers' Dried Grains

As distillers' dried grains are the product formed when most of the water is removed from the distillers' wet grains, they are similar to the brewers' dried grains in water content and keeping qualities. The use, in the distillery, of mixtures of grains which contain different proportions of corn, rye, or wheat, and barley, and differences in the details of the processes used in different distilleries results in considerable variation in the composition and value of the spent-grain residues. Corn distillers' dried grains are superior to rye distillers' dried grains in protein content, total digestible nutrients, and palatability. Both products are low in calcium.

The corn distillers' dried grains contain, on an average, about 28 percent of protein, 9 of fat, 12 of fiber, and 40 of nitrogen-free extract. The total digestible nutrients are about 80 and the digestible protein about 23 percent. Compared with brewers' dried grains, corn distillers' dried grains are a little higher in protein, considerably higher in fat and total digestible nutrients, and contain a little less fiber and nitrogen-free extract. These corn grains are higher in protein and total digestible nutrients than corn-gluten feed, and are highest of all the spent-grain feeds in total digestible nutrients. The corn distillers' dried grains are about 30 percent higher in nutrients than brewers' dried grains.

The rye distillers' dried grains contain only about 17 percent of protein and 6 percent of fat, and their fiber content averages 15.5 percent. Their digestible protein content is only 10 to 12 percent and their total digestible nutrients about 60 percent. This feed ranks among the lowest of the concentrate feeds in total digestible nutrients and is worth little more than good quality hay and less than brewers' dried grains.

As the proteins in the distillers' dried grains are derived chiefly from the cereal grains, the deficiency in some of the essential amino acids makes it necessary to include other types of protein concentrates in the ration. High quality roughage and some form of calcium carbonate are also required.

For Dairy Cows: Corn distillers' dried grains are a good source of the additional protein and fat required in a diary ration, and, they are palatable. Fairly large quantities may be fed without objectionable effects on the quality of the milk or the condition of the animal. For high-producing cows, the corn distillers' dried grains should not exceed one-fourth of the total quantity of grain fed.

Rye distillers' dried grains may be used in much the same manner as the corn grains, but are far less valuable because of the smaller content of proteins and digestible nutrients and the poorer quality of the protein. Their use is not economical unless their price is considerably lower than that of wheat bran and farm grains and not above that of good hay.

For Beef Cattle: Distillers' dried grains may be used to advantage as a source of part of the protein in beef cattle rations, especially those for fattening steers. If cheaper per ton than corn, corn distillers' dried grains may not only be used as the protein supplement but may also replace some of the grain of the ration. The rye distillers' dried grains are safe to use only in smaller quantities.

For Horses: Corn distillers' dried grains may constitute as much as one-third of the concentrate mixture for horses. As these grains are less palatable to some horses than to others, a gradual introduction and possibly a lower limit in the ration may be found necessary.

For Sheep: Distillers' dried grains may form as much as one-half of the grain ration for sheep and fattening lambs. If fed in larger proportions, some other type of protein concentrate is required to make up the deficiencies in essential amino acids, characteristic of cereal grain proteins.

For Hogs: Because of their bulkiness, distillers' dried grains are undesirable for fattening hogs, in quantities in excess of 15 to 20 percent of the ration. Larger quantities result in lower rates of gain, softer fat, and poorer finish. Results are better if both pasture and a protein supplement of a different type, such as tankage, are used with the distillers' dried grains and farm corn mixtures. If distillers' dried grains are cheaper than farm grain they may be fed to brood sows economically in considerably greater proportions than to fattening hogs.

For Poultry: The high fiber content of corn distillers' dried grains makes it necessary to limit their use in poultry feeding to about the same quantity as oats. Up to this limit, however, their protein content gives them considerable value. Corn distillers' dried grains are probably best used in a carefully planned mixture which includes noncereal protein concentrates and other feedstuffs which are low in fiber. The rye distillers' dried grains are not desirable for poultry because of their high content of indigestible matter and lower protein value.

Distillers' Solubles

Distillers' solubles, semi-solid or dried, contain all the dry matter from distillers' thin slop; distillers' grains with solubles contain all the dry matter from distillers' whole slop. The solubles contain yeast and other micro-organisms and the vitamins formed by them and are therefore good sources of vitamins of the B group. The solubles are economical sources of thiamin and riboflavin. If dried, the various products containing solubles are well-adapted to use in mixed feeds. Certain of the concentrated slops or solubles, especially those from the manufacture of some of the special distilled products, are such rich sources of some of the vitamins of the B group, that special processes for their recovery have been developed and proprietary vitamin supplements are manufactured from them. Various commercial feed mixtures containing the distillers' solubles are highly recommended by their producers as concentrates, rich in vitamins.

Most of the distillers' solubles and related products are used in the manufacture of commercial feed mixtures. However, if available, these distillers' products may be used advantageously by farmers in feeding the various classes of livestock for which the thin slop, thick slop, and distillers' grains have been found satisfactory. They should be used in the combinations recommended for the slop and spent grain and, usually, only in such quantities that the dry matter provided by them would be equal to the dry matter contained in the recommended quantity of the corresponding distillers' slop or grain. However, it is probable that beef cattle, dairy cattle, and other stock, for which the limit was based on the capacity of the animal, may safely be fed distillers' solubles or distillers' grains with solubles in quantities which provide considerably more dry matter than is provided by the large volume of whole slop or the quantities of the very perishable wet grains recommended. If, as in the case of swine, excessive feeding of distillers' products tends to cause lowering in carcass quality and rate of gain, the limitation of the quantity of solubles or grains with solubles on the basis of dry-matter content should be strictly observed. In the feeding of poultry, good results may be expected if not over 10 to 15 percent of the semi-solid solubles are included in a ration that contains other protein feedstuffs and meets all other requirements. The replacement of a part or all of the corn in the ration by distillers' solubles lowers the quality of the finished birds. Fair results have been claimed for the use of two parts of semi-solid solubles to one part of mash and also for the replacement of 80 percent of the corn in the mash by semi-solid solubles.

VINEGAR AND YEAST BYPRODUCTS

In the manufacture of vinegar from malt, fermentation of the sugars to alcohol is followed by the conversion of the alcohol into acetic acid by specific bacteria. The spent grains, when collected and dried, are the vinegar dried grains.

If cereal grains are used for the growing of yeast, the spent grains, when dried, are the yeast dried grains.

The dried grains from vinegar and yeast manufacture are so similar to the distillers' dried grains that they are ranked about equal in feeding value and are subject to the same quantity limitations in feeding rations.

YEAST AS A FEED

Yeast is fed in this country chiefly for its content of vitamins of the B group and, if irradiated, for its vitamin D content. It is used in small quantities in the preparation of fermented mashes. The high content of protein of good quality and its digestibility make yeast rank high as a protein supplement. The relatively high cost of yeast and the wide distribution of the several vitamins of the B group and also of proteins in more economical feeds, however, make it desirable to attempt to satisfy the animal's requirements through careful selection of feedstuffs which make up the ration and to use the yeast only when the nutrient requirements cannot be satisfied by other feeds. If yeast is fed to prevent or to overcome the effects of vitamine deficiencies, it is obvious that the better the basic ration, the smaller will be the benefits from the addition of yeast. As improvements in the processes for the reocvery of yeast as a byproduct of the fermentation industry, and further developments in the production of wood-sugar yeast further reduce the price, yeast may beco e a more practical source of protein and vitamins.

Actually, very little is known about the quantities of the vitamins of the B group required by the various farm animals. There is evidence that most of the members of the B group are synthesized in the rumen of cattle, sheep and goats. There is still doubt, however, whether this synthesis can be depended on to meet the requirements of these animals under some conditions. It was thought that some of the B vitamins were not required by hogs, but the raising of hogs on simplified diets and under close confinement has revealed the fact that they do need thiamin, niacin, pantothenic acid, pyridoxine, and choline -- vitamins of the B group.

The practice of fermenting mash for farm animals is open to question from the standpoint of economy. In fact, feeding experiments indicate little, if any, improvement in production results from the fermentation of the mash although growth of yeast increases the vitamin content and the quality of a part of the protein, and the ration is rendered slightly more digestible by enzyme action and softening. The increase in the cost of feeding, that is, the cost of the added yeast, the extra labor involved, and the small loss in energy value by carbohydrate destruction, is not covered by increase in production.

For Cattle, Sheep, and Goats: As the synthesis of the vitamins of the B group, which takes place in the rumen of cattle, sheep, and goats, appears to provide an adequate supply of these vitamins under normal conditions, the inclusion of yeast for its content of the B vitamins is likely to increase the cost of the ration unwarrantedly. In the dry-feeding of calves, however, the substitution of 5 or 6 percent of dried brewers' yeast or cereal-yeast feed (a combination of brewers' yeast, corn-gluten feed, and corn-germ meal) for a quantity of dried skim milk of equal protein content, in the dry starting mixture, has resulted in increasing the rate of growth of the calves.

Brewers' dried yeast and yeast-cereal feed are good protein supplements for dairy cattle and cause some increase in milk production, but their use is not economical unless they can be purchased at a price low enough to provide protein at as low a cost as other high-protein feeds, which have a similar protein content.

The feeding of irradiated yeast to dairy cattle increases the vitamin D content of the milk and this increase is roughly proportional to the added quantity of vitamin D fed, but the greater portion of the vitamin is destroyed or is excreted in the feces. To increase the vitamin D content of milk by feeding irradiated yeast, it is recommended that the yeast be fed to the cow at milking time and that the quantity fed be based on the milk production of the individual cow. Large scale commercial production of vitamin D-enriched milk is usually accomplished by direct irradiation of the milk or by the addition of vitamin D concentrates to the milk.

Lambs showed somewhat better growth and gain, calculated on the basis of the quantity of feed consumed, when yeast was included in experimental rations but when the calculations were based on the cost of the feed these gains were not economical.

For Hogs: The use of yeast, cereal-yeast feeds, or yeast and mineral mixtures in feeding hogs, is primarily to furnish vitamins of the B group, or these vitamins and minerals. In this country it is usually possible, as well as more economical, to satisfy all nutritive requirements by better selection of the major constituents of the ration and thereby avoid the added expense of the inclusion of yeast.

Some experiments have shown that a ration of corn and tankage or milk was deficient in niacin 3/ and that addition of sufficiently large quantities of yeast to this ration was beneficial. Also, oats treated with yeast cultures have been found to be no more valuable for hogs than the untreated oats.

In Germany, yeast manufactured from wood sugar has been fed, with some success, to swine in quantities sufficient to meet the protein requirements as the sole source of protein.

For Poultry: Various and sundry benefits resulting from the addition of yeast to poultry rations have been claimed. The poorer the ration, the more conspicuous are the benefits to be derived from the addition of yeast. If the ration consist of grains other than yellow corn and only other plant products as protein concentrates, it is low in both carotene and riboflavin. These deficiencies are usually economically satisfied if alfalfa-leaf meal, greenstuffs, and milk byproducts are included in the ration. As the form of vitamin D present in irradiated yeast shows very low activity for chicks in comparison with the highly active forms in vitamin D-activated animal sterol, vitamin D feeding oil, vitamin A and D feeding oils, or cod-liver oil, it is far more economical to depend on these oils as sources of vitamin D and at the same time obtain their vitamin A content.

3/ The average niacin content in milligrams per pound of a few feedstuffs are: Barley, 20; corn, 6; corn dried solubles, 45; corn-gluten feed, 47; rice bran, 129; rice germ, 70; wheat, 23; wheat bran, 63; wheat shorts, 45; some drie grasses and hay, 30 to 40; liver;(dried), 450; yeast, 190; and tankage, 30.

APPENDIX

Terminology

In the text the author has shown the sources of the products and, in both text and tables, has used the names which have been approved or proposed by the Association of American Feed Control Officials, an organization of Government officials and others interested in the promotion of uniformity in legislation, definitions, and rulings, and in the enforcement of laws relating to the manufacture, sale, and distribution of feedstuffs and livestock remedies in North America.

This Association's definitions or tentative definitions of certain of the newer and less familiar products mentioned in the text or included in the tables are as follows:

"Corn Distillers' Dried Grains is the dried residue obtained in the manufacture of alcohol and distilled liquors from corn, or from a grain mixture in which corn predominates. (Proposed 1941.)

"Rye Distillers' Dried Grains is the dried residue obtained in the manufacture of alcohol and distilled liquors from rye, or from a grain mixture in which rye predominates. (Proposed 1941.)

"Corn Distillers' Dried Grains With Solubles is the dried residue obtained in the manufacture of alcohol and distilled liquors from corn, or from a grain mixture in which corn predominates, and contains the major portion of the condensed screened stillage dried therewith. (Proposed 1941.)

"Rye Distillers' Dried Grains With Solubles is the dried residue obtained in the manufacture of alcohol and distilled liquors from rye, or from a grain mixture in which rye predominates, and contains the major portion of the condensed screened stillage dried therewith. (Proposed 1941.)

"Corn Distillers' Semi-solid Grains With Solubles is the residue from the manufacture of alcohol and distilled liquors from corn, or from a grain mixture in which corn predominates, obtained by condensing to a syrupy consistency the entire stillage contained therein. (Proposed 1941.)

"Rye Distillers' Semi-solid Grains With Solubles is the residue from the manufacture of alcohol and distilled liquors from rye, or from a grain mixture in which rye predominates, obtained by condensing to a syrupy consistency the entire stillage contained therein. (Proposed 1941.)

"Corn Distillers' Semi-solid Solubles is the product obtained in the manufacture of alcohol and distilled liquors from corn, or from a grain mixture in which corn predominates, by condensing to a syrupy consistency the screened stillage obtained therefrom. (Proposed 1941.)

"Rye Distillers' Semi-solid Solubles is the product obtained in the manufacture of alcohol and distilled liquors from rye, or from a grain mixture in which rye predominates, by condensing to a syrupy consistency the screened stillage obtained therefrom. (Proposed 1941.)

"Corn Distillers' Dried Solubles is the product obtained by drying Semi-solid Corn Distillers' Solubles. (Proposed 1941.)

"Rye Distillers' Dried Solubles is the product obtained by drying Rye Distillers' Semi-solid Solubles. (Proposed 1941.)

"Vitamin A & D Feeding Oil is either fish or fish liver oil or a blend of two or more of the following: Vitamin A and/or D concentrates, synthetic vitamin D, fish liver oil, fish oil, marine animal oil, or edible vegetable oil. The vitamin potency shall be stated in A. O. A. C.1/ chick units of vitamin D and U. S. P.2/ units of vitamin A per gram. (Proposed 1939--Amended 1941.) (NOTE)--This is an emergency definition and can be used only for the calendar year 1942.

"Vitamin D Feeding Oil is either fish or fish liver oil or a blend of two or more of the following: vitamin D concentrate, synthetic vitamin D, fish liver oil, fish oil, marine animal oil, or edible vegetable oil. The vitamin potency shall be stated in A. O. A. C.1/ chick units of vitamin D per gram. (Proposed 1940--Amended 1941.)
(NOTE)--This is an emergency definition and can be used only for the calendar year 1942.

"D Activated Animal Sterol is a product which is obtained by activation of a sterol fraction of animal origin with ultra-violet light or other means. For label identification it may be followed with the parenthetical phrase "Vitamin D." (Proposed 1940--Amended 1941.)"

In most States feed-control laws have been enacted requiring that labels on mixed feeds give a guaranteed analysis which states the minimum percents of crude protein and crude fat and the maximum percent of crude fiber and also the ingredients present in the mixture.

The term "total digestible nutrients" is used for the approximate energy evaluation and is calculated from the percents of digestible nutrients. In this calculation, fat is given a value of 2.25 and the other nutrients 1.00 for each percent.

1/ Association of Official Agricultural Chemists
2/ United States Pharmacopoeia

Table 1.--Average composition of yeast and byproducts of the fermentation industries

Feedstuff	Moisture	Protein	Fat	Crude fiber	Ash	Nitrogen-free extract	Digestible protein	Total digestible nutrients
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Brewers' dried grains								
below 23% protein	7.7	21.1	6.9	17.6	4.0	42.9	15.0	62
23.00 - 25.99% protein	7.4	24.6	6.4	16.2	4.2	41.2	18.0	
above 26% protein	7.2	27.5	6.7	15.3	3.9	39.4	21.0	66
Brewers' wet grains	75.6	5.6	2.0	4.3	1.0	11.5	4.3	16.7
Brewers' spent hops	6.2	23.0	3.6	24.5	5.3	37.4	6.7	29.0
Distillers' wet grains	77.4	4.5	1.6	2.8	0.6	13.1	3.2	19.0
Distillers' whole slop	93.8	1.9	0.6	0.5	0.3	2.9	1.3	5.3
Distillers' strained slop	95.9	1.4	0.7	0.2	0.3	1.5	1.0	3.7
Corn distillers' dried grains	7.1	28.2	9.0	12.2	2.6	40.9	22.6	80.0
Rye distillers' dried grains	6.8	17.0	6.0	15.6	2.4	52.2	11.0	57.0
Corn distillers' dried centrifuge sludge*	8.0	42.0	9.0	7.0	3.0	31.0		
Corn distillers' dried solubles*	8.0	27.0	7.0	0.8	8.0	49.2		
Corn distillers' semi-solid solubles**	60.0	12.0	3.0	0.4	3.5	21.1		
Corn distillers' dried grains with solubles*	8.0	28.0	9.0	7.0	5.0	43.0		
Corn distillers' oil-extracted dried grains with solubles*	8.0	31.0	1.0	8.0	5.0	47.0		
Malt	7.7	12.4	2.1	6.0	2.9	68.9		
Malt sprouts	7.6	27.2	1.6	13.1	5.9	44.6	19.7	74.4
Vinegar dried grains	6.8	19.5	7.0	17.3	2.9	46.5	12.5	62.3
Yeast dried grains	6.3	20.8	6.3	16.1	2.8	47.7	13.3	61.1
Yeast	4.3	50.0	0.5	0.5	10.0	34.7	40.0	75.0

* Values calculated to an 8 percent water content--actually samples ranged from 7 to 12 percent water.

** Semi-solid solubles calculated to a 60 percent water content.

Table 2.--High and low values* for constituents of some of the byproducts of the fermentation industries

Byproduct	Description of value	Moisture	Protein	Fat	Crude fiber	Ash	Nitrogen-free extract
		Percent	Percent	Percent	Percent	Percent	Percent
Brewers' dried grains: Below 23% protein	low	5.38	18.43	5.09	14.53	3.24	40.11
	high	9.49		8.67	19.59	5.53	46.01
23-25.9% protein	low	3.75		4.97	13.18	3.01	31.93
							35.20
	high	10.45		7.91	19.29	11.39	44.65
						7.85	46.50
Above 26% protein	low	5.00		4.98	12.96	2.90	34.18
	high	10.76	31.00	8.18	19.75	5.20	45.96
						7.17	
Corn distillers' dried grains	low	2.08	14.22	4.07	5.99	1.15	32.73
			21.94	6.35	6.70		33.13
	high	11.30	31.94	12.88	18.46	4.75	45.12
				13.18		5.10	56.49
Rye distillers' dried grains	low	4.35	12.99	4.41	12.36	1.00	45.56
		5.24		4.92			48.06
	high	9.38	20.18	8.06	18.86	6.05	55.75
		11.46	21.67			6.65	56.82
Malt sprouts	low	6.00	23.25	0.06	5.61	4.16	37.98
		6.10	23.58	0.60	10.70	4.44	38.80
	high	8.96	31.50	2.60	15.94	6.41	45.50
		10.15	32.40	3.28	16.08	8.12	47.40

* The values in this table have been selected from the large number of analyses covered in table 1. The values listed in horizontal lines are from as many different samples as there are constituents reported. Two values for eigher high or low constituents have been given if there was a large difference between the extreme value and the value nearest to it.

Table 3.--Composition of a few miscellaneous feedstuffs

Feedstuff	Moisture	Protein	Fat	Crude fiber	Ash	Nitrogen-free extract	Digestible protein	Total digestible nutrients
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Alfalfa-leaf meal	8.5	20.9	2.6	15.7	14.4	37.9	--	--
Barley	9.6	12.8	2.3	5.5	2.9	66.9	10.0	79
Beet pulp, dried	9.2	9.3	0.8	20.0	3.2	57.5	4.7	71
Corn	12.9	9.3	4.3	1.9	1.3	70.3	7.0	80
Corn-gluten feed	9.5	27.6	3.0	7.5	6.0	46.4	22.0	78
Corn silage, mature	70.9	2.4	0.9	6.9	1.4	17.5	1.4	20
Cottonseed cake or meal	7.3	41.0	6.5	12.0	6.0	27.2	31.0	70
Linseed meal (old process)	8.5	38.0	5.6	8.0	5.5	34.4	29.0	78
Oats	7.7	12.5	4.4	11.2	3.5	60.7	9.5	66
Oat hulls	5.8	4.3	1.9	30.8	6.5	50.7	2.2	59
Oat millfeed	6.9	6.3	2.2	27.9	6.0	50.7	4.6	43
Rye	9.0	11.1	1.7	2.1	1.9	73.7	9.3	80
Wheat	10.6	12.0	2.0	2.0	1.8	71.6	9.1	75
Wheat bran	9.4	16.4	4.4	9.9	6.4	53.5	12.5	63